to coagulate, and when the quantity injected is insufficient to kill, the blood (drawn off after injection) may remain uncoagulated for some days. In either case coagulation of shed blood may be induced by the addition to it of the liquid which has been injected. It therefore appears that the agent which brings about coagulation, *intra venas*, must disappear in the act of coagulation. The shed blood contains only a minute trace of fibrin ferment.

The acetic acid precipitate is soluble* in 0·5 per cent. HCl solution. On digesting this solution at 37°, after the addition of pepsine, a part of it is converted into peptone, but a precipitate appears in the process which is permanent. When the digestive products (peptone and precipitate), having been rendered alkaline, are injected into the circulation, no effect is produced.† There is neither intravascular coagulation, nor is the blood deprived of its power of coagulation; but if fresh acetic acid precipitate be added to the liquid, both effects follow injection. Consequently, the failure of effect when the products of digestion are injected alone, is not due to presence of pepsine or peptone. I have ascertained that the acetic acid precipitate does not cause coagulation of dilute magnesium sulphate plasma, which coagulates readily on the addition of fibrin ferment. The agent, therefore, in producing intravascular coagulation cannot be identified with that body.

II. "A Further Enquiry into a Special Colour-relation between the Larva of *Smerinthus ocellatus* and its Food-plants." By EDWARD B. POULTON, M.A., of Jesus and Keble Colleges, Oxford. Communicated by Professor J. S. BURDON SANDERSON, F.R.S. Received January 26, 1886.

CONTENTS.

1. *Introductory.*

In my previous paper upon this subject ("Proc. Roy. Soc.," No. 237, 1885, p. 269), I gave an account of some breeding experiments under-

* As casein is "soluble" in milk.

† The total quantity of peptone is very small.

taken in 1884 in which the larvæ of *Smerinthus ocellatus* were fed upon various food-plants, and the resulting larval colours were carefully compared. I also described the colours of captured larvæ of the same species, and mentioned the trees upon which they had been found. I was extremely anxious to continue the investigation in the following year (1885) in order chiefly to throw further light upon the two following points:—

(1.) By means of experiments and observations I had been enabled to show that the colour of the larva was in most cases affected by the food-plant, but there remained a certain number of exceptions which had to be accounted for. I suggested that these might be explained by supposing that the tendencies towards certain colours which were produced by particular food-plants in one generation became independent larval tendencies in the next, which might modify or overcome the usual effects of the food-plants; and that such transmitted influences augmented as the number of generations upon one food-plant (or others producing similar effects) increased. I was desirous of testing this theory by breeding from moths of which the history in the larval state was accurately known.

(2.) In my last paper I also pointed out that there was considerable evidence for believing that the influence of the food upon the larval colour is not a comparatively simple phytophagic influence, but one which is exceedingly complex, being brought about by the colour of part of the leaf (the part which the larva resembles), acting as a stimulus to some larval sensory surface (presumably the ocelli) and so through the nervous system regulating the amounts and kinds of the vegetal pigments absorbed and made use of, and that of the larval pigments deposited.

I wished to test this theory by feeding the larvæ under such conditions that they could only be affected by the colour from one side of the leaves of their food-plant, and it seemed that the best way of achieving this object was by sewing the leaves together. In the subsequent experiments the edges of the leaves were at first pared with the scissors to make them correspond, but it was afterwards found better to double each single leaf longitudinal and sew together the opposite margins which were thus brought into contact. The intention of the experiment was to compare the larvæ which had been exposed to the colour of the under sides of the leaves only, with those which had been exposed to the upper sides only, and with those which had been fed upon the normal leaves. If the larval colours varied according to these three sets of conditions, it would be quite clear that the larvæ were only influenced by the colour of the leaf-surface, because the leaf-substance eaten (from the edge through its whole thickness) must have been identical in all three cases. I also wished to vary the experiment by feeding some larvæ upon leaves which had

been given a different tint artificially by removing the "bloom" from the under surface, and to test whether the ocelli formed the impressionable part of the larvæ by investigating the effect upon colour of covering these organs with some innocuous opaque pigment.

I also wished to further investigate the effect of certain food-plants, about which the evidence was conflicting, and to carefully watch for instances of individual variation among the larvæ from the same batch of eggs and fed upon the same food, to look out for any indications which would throw light upon the red-spotted varieties, and also to further enquire into the periods during which the larvæ are most susceptible to the influence of the food-plant.

As far as these questions could be answered by work in the field, I was very successful, for the larvæ were even more abundant than in the summer of 1884, and I was able to extend my area of observation to Switzerland. I have also been exceedingly glad to be able to reconcile the conflicting evidence given in my last paper. But the breeding experiments did not yield adequate results, considering the immense amount of labour bestowed upon them. In the first place the moths emerged in an unfortunate order—a great many males, and later a great many females. Then of those which emerged together, there was great difficulty in obtaining such a system of pairing as I was desirous of instituting, the result being that I could get no larvæ with a strong hereditary tendency towards the yellowish variety; and these I was most anxious to obtain, because all my bred larvæ in 1884 tended very strongly in the opposite direction. The eggs I obtained in nearly all cases resulted from pairing the moths which came from these bred larvæ (1884). Although disappointed in the pairing of the moths, it seemed likely that the experiments would yield sufficiently convincing results from the very comprehensive scale on which they were conducted, for in July, 1885, I had many hundreds of young larvæ belonging to five different families. After the great labour of bringing this large number through the most delicate period of their lives, and just before the results appeared, the larvæ began to die off in hundreds, so that only seventy-five lived to an age at which trustworthy observations could be made. I can only suggest that this altogether exceptional mortality may have been due to the excessive heat and dryness which prevailed at the time. I do not think that it can have been due to the fact that both parents of the majority of the 1885 larvæ resulted from larvæ belonging to the same batch in 1884, because such interbreeding among moths does not produce injurious effects, at any rate until after it has been continued for many generations. Besides, in one instance, the larvæ were the offspring of parents which came from quite different localities, and these did not succeed any better than the others. But although a very small proportion of the larvæ survived, they were

still fairly numerous, and formed a considerable body of evidence bearing upon the questions alluded to above, and giving distinct answers to all of them, except the one which bears upon the time of life during which the larvæ are most susceptible to the influences of the environment, and that which suggests the ocelli as the sensory surface which is influenced.

Before describing the experiments in detail, I wish to express my sincere thanks to my wife for her kind help in the labour of attending to so many larvæ, and in the troublesome work of sewing the leaves together. Mr. G. C. Druce has also kindly supplied me with the branches of certain species of food-plant when I was away from home, and has rendered me invaluable assistance in naming the sallows. Mr. J. G. Baker, of Kew, also kindly named the Swiss sallows, of which specimens were sent to h'm by Mr. Druce.

2. *Experiments upon the Larvæ of* Smerinthus ocellatus *during* 1885.

The following experiments are arranged in five different series, belonging respectively to five different batches of eggs. There is complete uncertainty as to the male parent (if any) in Series II, and consequently there is some doubt thrown over the male parent in Series III, because in these cases (alone) the same female laid two batches of eggs. The cause of the uncertainty is explained at the beginning of Series II. The series are arranged in a succession which corresponds to an advance in the (presumably) hereditary tendency from the whitish towards the yellowish variety. And so also in each series the different sets of experiments are arranged in an order which corresponds to a similar advance in the tendencies known to be produced by the food-plants, *i.e.*, beginning with apple and ending with *Salix rubra.*

But the order is merely provisional in the case of less definite tendencies, or of plants which are little known as food-plants. It must also be remembered that the difference between the hereditary tendencies of the various series is very small, because of the failure (except in one case in which very few larvæ lived) to obtain any eggs from moths which came from yellowish larvæ.

Series I.

Eggs were laid in June, 1885, by a female moth bred from a larva which had been fed during 1884, for the whole period of larval life upon ordinary apple, and which was a typically whitish-green variety (mentioned in "Proc. Roy. Soc.," No. 237, 1885, p. 300). The eggs were fertilised by a male moth bred from a larva which had been fed upon crab for the whole of its life, and was a similar whitish variety (also mentioned on p. 300). Hence the inherited tendencies must have been strongly towards the whitest variety of this larva.

Out of a large number of larvæ which hatched at the beginning of July, 1885, a very small proportion lived until they were old enough to be of use in the present investigation. A careful examination of the survivors was made on August 12th, with the following results:—

1. *Pyrus Malus* (*var. acerba*).—Five larvæ (including one which was found after escaping, and which almost certainly belonged to this lot) were hatched on July 2nd, and now four were well in the last stage and one was changing its last skin. All five were extreme whitish varieties. Eventually all these larvæ died, but their colour was unchanged, and they were sufficiently advanced to warrant the conclusion that no further alteration would have taken place.

2. *Populus tremula, &c.*—One larva, hatched July 2nd, was now (August 12th) changing its skin for the last time and seemed to be a whitish variety. By August 20th it was well in the last stage and an intermediate variety, and without further change on August 27th, when it was nearly full-fed (ceasing to feed in a day or two). After the first fortnight the larva was fed upon a somewhat similar species of poplar, which I have not yet been able to name with certainty.

3. *Salix babylonica.*—One larva (hatched July 3rd) had now entered upon the last stage, and seemed to be well on the yellowish side of an intermediate variety. This description especially applied to the back, but there was a blueness about the ventral surface and lower part of the sides which is never seen in a true yellowish variety. On August 20th the larva was still on the yellowish side of intermediate, but not to such an extent as that seen in larvæ of Series III, which had been fed upon the same plant. Later, the larva became less yellow, so that by August 27th it was distinctly intermediate, and remained without further change until September 3rd, when it ceased feeding.

4. *Salix amygdalina, July 4th—13th, S. triandra, July 13th—14th, and S. rubra, July 14th, onwards.*—One larva (hatched July 4th—5th) was changing its last skin and apparently whitish. Another larva had died at the beginning of the last stage, and was also whitish. The former was dead by August 20th, so that no results were obtained from these larvæ, except the fact that the tendencies of the food-plants (towards producing the yellowish varieties) had evidently been largely counteracted in these larvæ. This larva is afterwards described as if fed upon *S. rubra*, for the leaves were selected so as to be similar to those of this tree in their effects.

The effects of hereditary influence are certainly seen in the larvæ of this series. The parent larvæ were extreme white varieties, and belonged to a group which evidently inherited a very strong tendency in this direction, as was shown by the comparatively slight effect that followed the use of foods which most powerfully tend to produce yellow varieties. It is certain that more dependence can be placed

upon this proof of a larval tendency, than by trusting to the maximum results obtained by the use of food-plants which tend to produce white varieties; because the power of the latter is so great as to afford no means of discriminating between larvæ with different tendencies except when the latter are very exceptionally strong in the direction of yellow. (For the proof of the strong tendencies of the parent larvæ, and an account of the effects of various foods upon them, see "Proc. Roy. Soc.," as above quoted, pp. 298—300.) The larval tendencies in this case were even stronger than in the parents, having been augmented by inheritance from the latter. Crab, which has no power in checking the tendency towards white (I cannot yet believe that it causes white itself) produced the most extreme white varieties in these larvæ as in their parents (No. 1). But *S. rubra* (with other similar foods unavoidably used during absence from home) evidently produced less effect than in the case of the parents (No. 4), and the same is true of *Salix babylonica* (No. 3) if we assume that this plant acts in the same manner as *S. rubra.* No conclusions can be drawn from the effects of *Populus tremula*, &c. (No. 2), because this is, I believe, the only instance yet recorded of the larva feeding upon the food-plant in question.

Series II.

Eggs were laid by a female moth bred from a larva which had been fed during 1884 for the whole of its life upon *Salix viminalis,* and which became an intermediate variety with some tendency towards the whitish side. (The larva was one of those mentioned on p. 300 of the paper already quoted.) In the case of this moth it seemed likely that no fertile eggs would be laid, for coitus did not take place when I placed a male in the same box with it. After this I put several males in the box, but I did not witness any act of coitus, although I watched the moths constantly, and the act lasts for several hours in all the cases which have come under my notice. In the meanwhile the moth kept laying eggs which I put in a box by themselves and carefully labelled. The great majority of these eggs shrivelled up, but to my astonishment a few gave rise to larvæ which are considered under these series. Subsequently to the laying of these mostly infertile eggs I succeeded in artificially inducing coitus, with the result that a large number of fertile eggs were laid, which were kept separate and are considered under the next series. Inasmuch as many males were present in the box with the female, it would be obviously impossible to maintain that the larvæ of this series were parthenogenetically developed, but I may state in favour of such a view that in all other cases the coitus lasted long enough for me to witness it, and that nearly all the eggs behaved like those which were laid by other female moths without coitus. I may add that I always carefully separated the eggs which were laid before and after coitus, and

also that when several males were together in the same box with a female, the former were distinguished from one another by small notches in the wings.

The inherited tendency was probably towards the intermediate variety (arguing from the female parent only), because the parent larva was almost intermediate after feeding on *S. viminalis* for its whole life, although the group of larvæ to which it belonged tended strongly towards white.

The larvæ were examined on August 12th, with the following results :—

1. *Salix viminalis.*—Six larvæ (hatched July 10th) of which four were nearly full grown, and very similar, being good whitish varieties, though not so strong as those produced by apple. The two others are younger but apparently similar. By August 20th the four larger ones had all ceased feeding without any change of colour. The two smaller larvæ died.

2. *Salix Smithiana.*—Two larvæ were well in the last stage and were greener than those just described—perhaps intermediate varieties. By August 16th one of these was decidedly intermediate, while on August 20th it was well on the yellowish side of intermediate and very nearly full grown. It ceased feeding without further change on August 27th. The other larva died soon after August 12th. These larvæ were fed for a considerable time upon the upper twigs (bearing large leaves) of the doubtful species of Salix mentioned in the note on p. 301 of the paper quoted above. Such leaves were indistinguishable from those of *S. Smithiana.*

These results are certainly perplexing, for the larvæ upon *S. viminalis* (No. 1) were whiter than the parent larva which was fed upon the same plant (although the former probably represents the real tendency of the food-plant), while the one upon *S. Smithiana* (No. 2) was rather yellower than those which are generally produced by this plant, although the data are insufficient. On the other hand, there is nothing at all startling or violently opposed to the conclusions of the other series in the above results, which in one case are those normal to the food-plant, and in the other differ but slightly from the normal result. It must also be remembered that there is complete uncertainty as to the male parent (if any) of these larvæ.

Series III.

The eggs which produced the larvæ of this series were laid by the female moth described at the beginning of Series II. It was bred from a larva which had been fed upon *Salix viminalis*, and which became an intermediate variety with some tendency towards the whitish side. After laying the eggs which produced the larvæ of the last series, coitus was artificially induced with a male moth, bred from

a larva which had been fed for its whole life upon ordinary apple (mentioned at p. 300 of the paper quoted above), and which was a typical whitish variety. Hence the inherited tendencies were probably towards the white variety, somewhat modified in the direction of intermediate. Very many fertile eggs were laid after coitus, in June, 1885, and were hatched about July 10th, and although a large number died, a considerable mass of evidence was forthcoming from the fairly numerous larvæ which survived, and which were divided into nineteen sets of experiments. The results of the examination of these larvæ on various dates are given below :—

1. *Ordinary Apple.*—On August 12th two larvæ (hatched July 12—16) were examined, and were in the fourth stage and *very* white, with a peculiar transparent appearance, which seems to be often caused by this food-plant. On August 20th they were both dead, but there could be no doubt of the tendency of the food-plant in this case.

2. *Ordinary Apple.*—On August 12th four larvæ (hatched July 10th) were examined: three were in the last stage and one in the fourth; all were *very* white. On August 20th all were dead except one, which died on August 27th. There was no doubt about the extreme tendency of the food; but apple seemed extraordinarily fatal in its effects during this last summer.

3. *Ordinary Apple (the leaves sewn so as to expose the under sides only).*—One larva (hatched July 10th) was examined August 12th, when it was at the end of the fourth stage and *very* white. On August 20th it had entered the last stage, and was unchanged in colour. On August 27th it was dead. There could be no doubt about the strong tendency of the food, but the unsewn apple leaves produced such a maximum effect that there was no room left for the sewn ones to do more.

4. *Ordinary Apple (the leaves sewn so as to expose the upper sides only).*—Three larvæ (hatched July 10th) were examined August 12th, when they were young in the fourth stage and very white. By August 20th they were all dead, and so immature that it is impossible to draw any certain conclusions. It must also be noted that in the case of such broad leaves as apple, there is a constant tendency for the larvæ to expose considerable areas of the under surface by nibbling away part of one side of the leaf.

5. *Crab (Pyrus Malus, var. acerba).*—Four larvæ (hatched July 16th) were examined August 12th, when they were very small and apparently tending strongly towards the white variety. On August 16th one had died, and the others were only in the third stage. On August 20th they were still quite small and very white, and on August 27th they were all dead, except one which died soon after. As far as the observations went the larvæ were typically white, but

they were very small. Nevertheless it is improbable that there would have been any change from this strongly marked tendency.

6. *Salix viminalis.*—One larva (hatched July 11th) was well in the last stage when it was examined on August 16th; it was a whitish variety with tendencies towards intermediate. The larva was further examined on August 20th and 27th, and on the last date was slightly on the white side of intermediate. This is the last note upon the larva, which must have been full fed by this time.

7. *Salix viminalis.*—Five larvæ (hatched July 10th) were examined on August 20th, when one had ceased feeding a few days before, three were nearly full fed, while one was small. All were slightly on the white side of intermediate. The larvæ were again examined on August 27th, when only two were still feeding, but were practically mature, and were very slightly on the white side of intermediate. The small one had died. The results are final as regards the other four larvæ.

8. *Salix viminalis (the leaves sewn so as to expose the under sides only).*—One larva (hatched July 10th) was examined on August 12th, when it was in the fourth stage, and very white. It was again examined on August 27th, when it had been fed for about a week on the ordinary unsewn leaves of *S. viminalis.* It was well in the fourth stage and *strongly* white. The larva died shortly afterwards, but it is probable that the colour would not have changed.

9. *Salix alba.*—Two larvæ (hatched July 14 and 15) were examined on August 12th, when one was in the fourth stage and the other was well in the last stage. They were intermediate varieties, or perhaps rather on the yellowish side. On August 16th the younger one was dead without further change, and the older larva was examined on August 16th, 20th, and 27th, remaining on the yellowish side of intermediate until its death on the last of the above-mentioned dates.

10. *Salix Smithiana.*—On August 12th four larvæ (hatched July 10th) in the last stage were examined, and were found to be on the white side of intermediate. By August 20th three were dead, and the remaining larva was examined then and on the 27th. On the last date the larva was well in the last stage and slightly on the white side of intermediate, this being the last note taken, and certainly representing the final effect of the food. These larvæ were fed for a considerable time upon the upper twigs (bearing large leaves) of the doubtful species of Salix mentioned in the note on p. 301 of the paper quoted above. Such leaves were indistinguishable from those of *S. Smithiana.*

11. *Salix cinerea.*—Two larvæ (hatched July 10th) were examined August 16th, when one was well in the last stage and one in the third. The former was intermediate, the latter too young for any certain results. On August 20th the younger larva was dead, the older one being still intermediate, while upon August 27th it was

nearly full fed, and slightly upon the yellowish side of intermediate, this being the last note, and giving the final result.

12. *Salix cinerea.*—Three larvæ (hatched July 11th) were tolerably full fed when they were examined on August 16th. One was on the white side and one on the yellow side of intermediate, while the third was a yellowish variety (although not strongly yellowish). It was extremely interesting to note that the latter—the only undoubtedly yellowish larva yet obtained in my breeding experiments in 1884 and 1885—possessed traces of the red spots that occur commonly on the yellowish varieties of *S. ocellatus*. On the first five abdominal segments there was a little local darkening of the green borders to the oblique stripes occupying the position of the upper row of red spots, and in the centre of each dark spot there was an extremely faint tinge of red. There was also a very slight tendency towards the suffusion of the ground colour round the spiracles with a tinge of red. On August 20th the larvæ were as they have been described (except that the whitish intermediate larva was now intermediate), and were practically full fed. The yellowest one was a bright yellow variety (although there was but little yellow on the under surface, so that the larva was not one of the strongest varieties). On August 22nd the yellow variety and the intermediate larva had ceased feeding, while the yellowish intermediate larva became adult about August 25th. There was no further change in the colour of any of the larvæ.

13. *Salix cinerea.*—Three larvæ (hatched July 12th) were well in the last stage when they were examined on August 16th. One was on the white side of intermediate, and two intermediate or slightly on the yellowish side. On August 20th and 27th the larvæ were again examined and had progressed in the direction of the yellowish variety, so that on the latter date—when two had ceased feeding, and the other, though still feeding, was mature—they were all on the yellowish side of intermediate, although only slightly so in one case.

14. *Populus nigra.*—Five larvæ (hatched July 10th) were examined on August 12th, when four were in the last stage and one smaller. They were all whitish, but looked as though they were progressing in the direction of intermediate. On August 16th only two remained alive, one being well in the last stage and a whitish intermediate variety, while the other was whitish, being much smaller and not thriving. On August 27th the large larva was the only one alive and was advanced in the last stage, and a distinct intermediate variety without any tendency in either direction. This represents the final result, as the larva subsequently died without further change.

15. *Salix triandra.*—Eleven larvæ (hatched July 9—12th) — of which three were small, but eight were advanced in the last stage—were examined on August 12th, and were all intermediate varieties, as different as possible from those from the same batch of eggs which

were fed upon apple. On August 16th two of the eight large larvæ were quite clearly, though slightly, on the yellowish side of intermediate. On August 18th four ceased feeding, and on August 23rd three more without change of colour. The other larva and three small ones died.

16. *Salix triandra* (*without the whitish bloom upon the under side of the leaves*).—The bloom was for the first part of the time rubbed off with the moistened fingers, but afterwards a tree was found near the Oxford University parks, of which all the leaves were without the bloom, and the larvæ were fed upon this food for the later part of their lives. The following results afford a very interesting comparison with those given above, following the use of the ordinary leaves of *S. triandra* which presumably tend less towards the yellowish variety of larva than those supplied in the present instance.

Ten larvæ (hatched July 13—14th) were variously advanced in the last stage on August 18th, and on comparing them with those (see above) fed upon ordinary *S. triandra* (most of which were rather older), it appeared that the former would be considerably yellower when they had reached an equal age. There were also other younger larvæ upon the same leaves, of which the tendency could be better estimated at a later date. On August 23rd one had ceased to feed, and was distinctly on the yellowish side of intermediate. On August 27th the small ones had died without any results, while four of the older ones were full fed, and the others dead (although old enough to indicate what their colour would have been). The results were very uniform, all being on the yellowish side of intermediate, while only a small proportion of those fed upon ordinary *S. triandra* were at all beyond the intermediate form.

17. *Salix babylonica.*—Four larvæ (hatched July 10—11th) were well in the last stage on August 12th when they were examined. They had been fed on *S. triandra* for twenty-four hours (July 23rd—24th) because I was travelling and could not get the proper food. On August 12th they were all well on the yellow side of intermediate: they were again examined on August 20th and 27th, when two ceased feeding, one was practically mature, and one had died. The colour remained the same in all cases.

When examining these larvæ at an earlier date (August 3rd), when they were more numerous, I noticed one which was in the fourth stage, and which possessed the upper row of rust-coloured spots which are often found on the yellow varieties of these larvæ. The spots were present on the second thoracic segment (*very* faintly), and upon the first five and the seventh abdominal segment. To my great surprise I observed that the larva was distinctly whitish, and as I was most anxious to prove that such varities can bear the spots I changed its food from *S. babylonica* to apple (August 3rd). The next day the

larva ceased feeding before its last ecdysis, and it died on August 20th when advanced in the last stage, and an intermediate variety. Thus it is quite certain that the spots can appear on other than yellowish varieties.

18. *Salix rubra.*—Three larvæ (hatched July 10th) were well in the last stage on August 12th, when they were examined. Like those upon *S. babylonica* they had been fed for one day upon *S. triandra.* One was decidedly on the yellow side of intermediate, one less markedly so, and one was intermediate. On August 20th the two former were decidedly on the yellowish side, and I have a note to the effect that I was sure that they were yellower than the larvæ fed upon this tree last year (1884), and of which an account is given in the paper already alluded to. At this time the two yellower larvæ ceased feeding, while the third was still intermediate, and it ceased feeding about August 25th without further change.

19. *S. rubra.*—One larva (hatched July 10th) which had been fed for one day as above described upon *S. triandra* was examined on August 16th, when it was in the last stage and apparently on the yellowish side of intermediate. On August 20th it was advanced in the last stage and unchanged in colour, and on August 27th it was about full fed and slightly on the yellowish side of intermediate, and there is no doubt that this result was final, for the larva could not have undergone further change when it was so mature, this being the last note I have about it.

Reviewing these sets of experiments and comparing them with those of Series I and II, we find upon the whole considerable evidence for the existence of a hereditary force which influences the larval colour in this species.

Ordinary apple (Nos. 1 and 2) produces a maximum effect, as might be expected from previous experiment and observation. It would probably do so even if there existed a strong hereditary tendency towards yellow, and in this case the transmitted influence deviated but little from the direction of the typical white variety (as indicated by the life histories of the present larvæ). There is no doubt that a similar effect would have been produced in the other two series if the larvæ fed upon this food-plant had lived long enough to enable me to take reliable observations. (As this was not the case, such experiments were not alluded to in either series.) Since ordinary apple produced maximum effect, it was practically certain that the same result would follow the use of leaves which were sewn so as to show the white under sides only (No. 3). No. 4, in which the leaves of apple were sewn so as to show the upper sides only, did not terminate as I should have expected, as far as I could judge of the effects in the immature larvæ. The process of sewing and paring causes injury to the leaves, so that the larvæ did not thrive upon them (being less

healthy than they were upon the unsewn leaves, although they were far from healthy upon the latter during the past year). Nevertheless, I hope to succeed in the rearing the larvæ upon such leaves in a more favourable season, and I believe that some deviation from the extreme white variety will result (this conclusion being warranted by the results of other experiments described in the present paper). Nos. 1—4 were not represented in the other two series.

Crab (No. 5) produced white varieties, as far as could be ascertained, acting as it did on the present larvæ and in Series I (No. 1). It was quite as fatal in its effects as ordinary apple, and the larvæ seem to grow more slowly when fed upon it than upon any other plant, as was also noticed in the case of the parent larvæ. Considering the extreme effects following the use of this food in the other cases, it could hardly be expected that there would be any appreciable difference in the larvæ of this series.

Salix viminalis (Nos. 6 and 7) produced exactly the same effects as in the parent larvæ, while the larvæ of Series II (No 1) fed upon the same plant were fairly strong white varieties. This is a very strange contrast considering the parentage of the two series, but the uncertainty of the male parent in Series II prevents much importance from being attached to it.

The effect of *S. viminalis*, sewn so as to show the under sides of the leaves (No. 8), affords a most interesting comparison with the results of Nos. 6 and 7, for the former produced a strong white variety (that is up to the time of its death). Here is a distinct proof of the effect of the colour of one leaf-surface as apart from the leaf-substance eaten by the larva.

Salix alba (No. 9) cannot be compared with any previous experience of my own. I expected it to act like *S. viminalis*, but the larva was rather yellower than those which had fed upon the latter plant. The leaves of *S. alba* vary much in whiteness, the young leaves being far more downy and white than the older ones, so that a different effect is probably produced by the two kinds. There is independent evidence (Mr. Boscher's, which will be alluded to presently) that this food-plant produces white larvæ.

Salix Smithiana (No. 10) produced a larva which when mature was on the whitish side of intermediate. This is probably the normal result of the food which in this case coincided with the hereditary influence. In Series II (No. 2), however, the larvæ fed upon the same food-plant were rather yellower; hence the effects of *S. Smithiana* and *S. viminalis* in the two series were the exact converse of each other—a very perplexing result. At the same time, as already pointed out, there was nothing at all unusual in the results of any of the individual sets of experiments. (See also the notes upon the parentage of the larvæ of these two series.)

Salix cinerea (Nos. 11, 12, and 13) produced very interesting results, varying from a good yellow variety to intermediate, nearly all being upon the yellowish side of the latter. Thus, there is a distinct, though slight, advance upon the effect of this food on the parents in the direction of yellow.

The results obtained from the three larvæ of No. 12 are extremely interesting, showing that individual variation may sometimes play an important part in the colour produced, although the whole of the results of all observations and experiments conducted up to the present time certainly prove that such a factor is generally insignificant, and rarely causes any effects that can be detected. By individual variation I mean the development of a different colour than that which would be produced by the food-plant acting upon a larval tendency which is uniform for nearly all the larvæ from each batch of ova, the latter tendency being probably explicable as the inherited results of previous food-plants for many generations. In other words, I mean breaches in the uniformity, however caused, of the larval tendency, and a study of this and the previous paper upon the same subject, will show that such irregularities are comparatively rare, and especially so when the food-plant itself is known to possess a strong influence in the direction of either extreme of coloration.

Populus nigra (No. 14).—The results of this food-plant, intermediate as far as the evidence went, cannot be compared with any other experience, for this is, I believe, the only instance of the larvæ having been known to eat this food-plant. From the green glabrous undersides of the leaves I should have anticipated a tendency towards yellow, which was only partially verified.

Salix triandra (No. 15).—I was especially anxious to gain abundant evidence as to the effect of this food-plant, because I believed that its tendency was towards yellow. Mr. Boscher described numerous instances of typical white larvæ having been found on it. I have, however, since ascertained that Mr. Boscher was mistaken in his identification, and that the trees upon which he found the whitish larvæ were *Salix alba*, and such a result from the latter food-plant is what I should have anticipated. At the same time, I should wish to point out that the identification of the various species of Salix is immensely difficult, and that I have only been saved from hopeless confusion by the skilled assistance of Mr. G. C. Druce, who has most kindly helped me, and, when necessary, has obtained other opinions, throughout this investigation. During the past year (1885) I have proved by observation in the field (as will be seen) that the effect of *S. triandra* is to produce yellowish varieties, and the same thing is proved by these experiments, considering the hereditary influences. I have therefore verified the prediction upon which I ventured in my last paper (already quoted, p. 306), although at the time when the

paper was written, nearly all the evidence seemed to point the other way. The larvæ of this set were intermediate, inclining in some cases to the yellowish side. Hence the effects are the same as those produced by leaves which are known to cause the yellowish varieties as a rule. These results can be compared with no previous experience, as the larva has never been bred upon this tree (as far as I am aware), and I can find no instance recorded of its being found in the field upon this food-plant, except the instances which occurred in 1885 (to be described). These agree with the breeding experiments, as does the result of an experiment given in my last paper (quoted above, p. 303), in which *S. triandra* modified the colour of a whitish larva found upon *S. ferruginea.*

Salix triandra (No. 16, without the whitish bloom on the under sides of the leaves).—These results compare in a very interesting manner with those of the last set, the influence in the direction of yellow being more strongly marked than in the case of the usual leaves of this plant. The numerous larvæ of these two sets were repeatedly placed side by side and compared in the most careful manner, and there could be no doubt that there was a considerable difference in the predominance of yellow, while the larvæ had been subject to exactly the same conditions, except in the one point mentioned above.

Salix babylonica (No. 17).—The larvæ were all well on the yellowish side of intermediate (except the one which was put upon another food when quite young), and this result compares favourably with that of the larvæ of Series I upon the same plant (No. 3), where with the greater hereditary influence towards white the larva became an intermediate variety. In this case also the larvæ of the two series were examined side by side, so that there was no doubt about the difference. This result also compares favourably with the larvæ captured upon this food-plant during 1884.

Salix rubra (Nos. 18 and 19).—These results also compare well with No. 4 of Series I. As far as it was possible to judge from the immature condition of the larvæ in the latter set, the effect was not so yellow as in Series III. The effect produced in the present case was stronger than in the larvæ from the same set as the parents, which were fed upon *S. rubra.* This was to be expected, because the tendency of the latter was very strongly towards the white variety, while in the present instance it was somewhat modified.

Series IV.

Eggs were laid by a female moth, bred from a larva, which had been fed in 1884 for the whole of its life upon *Salix cinerea*, and which became an intermediate variety. (The larva was one of those mentioned on p. 300 of the paper quoted.) The eggs were fertilised

by a male moth bred from a larva which had been fed for its whole life upon *Salix rubra* (mentioned at p. 300), and which became a yellowish intermediate variety. The tendencies were thus presumably towards intermediate, or slightly on the yellowish side. A large number of eggs were laid, and nearly all of them hatched successfully, yielding apparently healthy young larvæ, but the most extraordinary mortality prevailed, so that no single larva arrived at maturity, or indeed at an age which would render any conclusions possible (except in the case of very marked colours which were not manifested). This is all the more to be regretted because I had reserved by far the greater part of this lot of larvæ for some experiments which would have conclusively decided some of the points in this difficult problem. A few larvæ were fed upon some of the same food-plants as in the other instances, in order to gain further evidence as to their effect. Thus larvæ were fed upon *Salix cinerea* (in this case it would have been interesting to ascertain the effect of the food upon two generations of larvæ, although the female parent only had been so fed upon *S. cinerea*) and upon *S. Smithiana* (the leaves sewn together so as to expose the under sides only). A few of the larvæ were blinded before they had seen the food-plant, by carefully painting over the ocelli with lamp-black, a lens being used to make certain that all of the ocelli were covered. This was a task of considerable delicacy and difficulty in the small and restless larva, but when once accomplished the larvæ did not seem any the worse, and behaved in every way as the others which were not blinded. As the lamp-black only formed an opaque film over the transparent cuticular covering of the ocelli, and as the former is thrown off at ecdysis, the pigment had to be renewed at the beginning of each fresh stage, and the greatest care was necessary to prevent the larvæ from changing their skins at unexpected times, and thus having the opportunity of seeing the food-plant. Hence any larva which had ceased feeding before ecdysis was isolated and only put back upon the food after it had changed its skin and the pigment had been renewed. Larvæ treated in this way were fed upon the two food-plants which tend most strongly in opposite directions—ordinary apple and *Salix rubra*, and at the same time large numbers of unblinded larvæ from the same batch of eggs were fed upon the same plants. Had the larvæ lived there must have been conclusive evidence as to one obvious theory of the origin of afferent impulses which determine the selection and the use of certain proportions of the mixed vegetal pigments, and the deposition of certain amounts and kinds of true larval pigments—the theory that such impulses are caused by the colour of one or both sides of the leaf acting as a stimulus by means of the ocelli. I am indebted to Professor G. J. Romanes for the suggestion that experiments should be made upon blinded larvæ, while Professor E. Ray Lankester advised

me to use some harmless pigment instead of silver nitrate. The lamp-black mixed in the usual way with Mc. Guilp. acted in every way satisfactorily, drying very quickly and being perfectly innocuous, and completely opaque. The possibility of future success was shown by these experiments, for the death of the larvæ was certainly not due to the conditions under which they were placed, as was shown by comparing them with the normal larvæ.

Further experiments were tried upon the larvæ from this batch of eggs, to ascertain if possible the exact periods of larval life which are most sensitive to the influence of the food-plant, as gauged by the persistence of effects after the change to another food-plant which tends in an opposite direction. Most of the larvæ were used in this series of experiments. A large number (forty or fifty) were fed upon ordinary apple, and about an equal number upon *Salix rubra.* At the end of the first stage a certain number (six) were shifted from apple to *S. rubra*, and an equal number from *S. rubra* to apple, and so with each succeeding stage. Thus if the larvæ had lived there would have been the following groups when they were full fed :—

1.	Fed upon ordinary apple during	stage 1,	and *S. rubra*,	stages 2–5.
2.	,, ,, ,,	stages 1–2,	,,	,, 3–5.
3.	,, ,, ,,	,, 1–3,	,,	,, 2–5.
4.	,, ,, ,,	,, 1–4,	,,	stage 5.
5.	,, ,, ,,	,, 1–5.		

And again,

1.	Fed upon *S. rubra* during	stage 1,	and upon ordinary apple,	stages 2–5.
2.	,, ,, ,,	stages 1–2,	,, ,,	,, 3–5.
3.	,, ,, ,,	,, 1–3,	,, ,,	,, 4–5.
4.	,, ,, ,,	,, 1–4,	,, ,,	stage 5.
5.	,, ,, ,,	,, 1–5.		

I think there is no doubt that a careful comparison of these ten groups (which would in all cases have been kept separate as soon as their food was changed) would have very completely answered the question of which the solution was sought in this series of experiments. I have given an account of these experiments—although they yielded no results owing to the unfortunate and altogether exceptional season—because it is likely that future work on these lines will be successful in throwing some light on this difficult subject, and because it is to be hoped that others may be induced to assist in these investigations.

Series V.

Eggs were laid by a female moth bred from a larva which had been fed during 1884 for the whole period of larval life upon *Salix rubra*, and which was rather on the yellow side of an intermediate variety. (The larva was one of those mentioned in the paper quoted

above, p. 300.) The eggs were fertilised by a male moth bred from a yellowish larva found upon *S. rubra* on the River Cherwell August 7th, 1884, and mentioned on p. 301 of the paper quoted above, as the larva in the last stage without the brownish-red spots. The larva had been fed upon apple from August 10th—18th, without causing any change of colour (see pp. 302 and 303). Thus the hereditary tendencies should be towards a rather strong yellowish variety, if they are due to a compromise between the tendencies of the two sexes. A large number of eggs were laid in June, 1885, which hatched at the beginning of July, but there was great mortality among the larvæ in all stages, but especially when they were very young. A careful examination of the few surviving larvæ was made on August 12th, all the others having died before the period at which it was possible to make any trustworthy observations of their colour.

1. *Salix viminalis* (*upper side*).—One larva (hatched July 2nd) had been fed upon the leaves of *S. viminalis*, folded and sewn so that only the upper side was exposed. The larva died August 10th in the last stage, after failing for some time; it was a very green intermediate variety, and although it had very little yellow about it, the contrast with larvæ fed in a normal way upon the leaves of this food-plant was most interesting (although the different parentage must be taken into account).

2. *Salix cinerea.*—Two adult larvæ (hatched July 2nd) had been fed upon this plant for their whole life. One was decidedly but not strongly on the yellowish side of intermediate; the other strictly intermediate. By August 20th both had ceased feeding without further change.

3. *Populus nigra.*—Two larvæ (July 3rd) had not thriven at all. One was in the fourth and one in the third stage; the former evidently tending towards the whitish variety, but they were too young for any certain conclusions, and by August 20th both were dead, without any further results.

The review and comparison of these results is, on the whole, disappointing.

Salix viminalis, upper side only (No. 1).—The result of this experiment was very interesting. The larva was frequently placed side by side with others upon ordinary *S. viminalis*, and the difference was extremely marked. I do not think that too much weight must be attached to hereditary influence in producing this effect, because the other sets of experiments in this series do not prove the influence to be as strong as I should have expected from the colour of the parent larvæ.

Salix cinerea (No. 2).—The effects compare unfavourably with those produced by this food-plant upon the larvæ of Series III (Nos. 11, 12, 13), for the latter were rather more strongly influenced in the

direction of yellow, while the hereditary tendency was presumably weaker. At the same time the effect was more marked than in the set of larvæ to which the parents belonged; and there was nothing at all unusual in the results themselves.

Populus nigra (No. 3).—There is little to be said about this result. The larvæ were too young to warrant any conclusion, but they were whitish when they died. At the same time the larvæ of Series III (No. 14), which were fed upon this food-plant were also whitish when young, while those that lived progressed in the direction of yellow; so that the most mature was an intermediate variety at the time of its death. It is probable that the larvæ of Series V may have also changed in the same direction if they had lived.

It is noteworthy that the strong hereditary influence in the direction of yellow, which we should suppose existed in Series V (because of the colour of the parent larvæ), depends chiefly upon the male parent; and how far this element asserts itself in opposition to the other sex is quite unknown in this class of experiment. Indeed, a large number of data of this kind might be valuable in gauging the relative strengths of the sexes in this form of heredity, but the present data are far too limited to be regarded as a serious contribution to this aspect of the subject.

3. *The General Results of the Breeding Experiments.*

It is now necessary to consider how far the questions suggested at the beginning of this paper have received answers from the experiments which have been detailed above.

(1.) With regard to the first question, it is, I think, certain that the larval tendencies towards certain colours are transmitted, as was proved by the fact that the parent larvæ had very strong tendencies towards the whitish variety, while in the next generation only a single yellowish form appeared out of seventy-five larvæ. On the other hand, there was conclusive evidence of the modified tendency towards white in the offspring following the change wrought in the parents by food-plants with strong tendencies. Thus, although food-plants such as *S. rubra* (tending strongly towards yellow) did not produce yellow varieties, yet the larvæ were, as a rule, yellower than in the case of the parents. There was no difference between the parents and offspring in the results of food-plants which tended strongly towards white, these being strong enough to overcome any ordinary hereditary tendencies. The results obtained by comparing the different series together are less conclusive, but it is unfortunate that a really satisfactory number of larvæ was only obtained in one case (Series III), the others being insufficient to afford any very convincing comparison. The comparison between Series I and III was certainly, as far as it went, in favour of a stronger tendency towards

white in the former series, such as we should expect from the parentage. Series II is the one about which there is so much obscurity, but its results were rather irregular when compared together and with those of the other series. In Series V we should expect a greater predominance of the yellowish tendency, if the male parent is of equal importance with the female in this respect, but the data were very insufficient.

But it must be clearly understood that the question is really settled, because of the wonderfully uniform results of the comparison between parents and offspring as a whole, in which comparison we are dealing with strong and definite tendencies; while in the case of the offspring we are considering delicate differences between such tendencies, which are obviously much more difficult to detect and need far larger data for their accurate determination.

(2.) As to the second question, I think it may be said that conclusive experimental proof has been afforded of the theory brought forward in my last paper—that the colour of the leaf, and not its substance when eaten, is the agent which influences the larval colours. It seems to me that this is proved by the breeding experiments in Series III, in which the larvæ from the same batch of eggs were whitish intermediate and white after being respectively fed upon *S. viminalis* and upon leaves of the same plant sewn so that only the under sides were visible (Nos. 6, 7, and 8).

On the other hand an intermediate variety was produced by feeding a larva from another batch of eggs upon similar leaves sewn so as to expose the upper sides. (Series V, No. 1.) The same thing is proved by a comparison of two sets of larvæ from the same batch of eggs, fed respectively upon *S. triandra* and upon the leaves of the same plant from the under sides of which the whitish bloom had been removed.

Concerning the food-plants, about which the evidence was conflicting, the experiments have in some cases helped to clear up the difficulties. The greatest of these difficulties concerned *S. viminalis* and *S. triandra*, but in the latter case there really was no confliction of evidence, as Mr. Boscher's white larvæ were found upon the very similar but much whiter *S. alba*. As to *S. viminalis*, the difficulty does not at first sight appear to be cleared up by the breeding experiments, but I will defer its consideration until after detailing my experience with captured larvæ, for what I believe to be the correct solution presented itself to me from the results of this part of the investigation. The experiments upon crab produced exactly the same results as in 1884: this will also be considered later. With regard to other food-plants, the view I previously expressed that *S. Smithiana* tends to produce whitish intermediate varieties, is on the whole supported, and so also in the case of *S. babylonica*, which as I

suggested, is similar in its effects to *S. rubra.* The effects of various plants hitherto untried have also been observed as a result of the experiments and work in the field.

As to the occurrence of individual variation in larvæ from the same batch of eggs and fed upon the same food-plants, it is now quite certain that such variation may take place, but any considerable divergence is very exceptional.

Thus in the twenty-three larvæ bred in 1884, there was practically no individual variation, while in 1885 there were only eight instances out of seventy-five larvæ, and in none of these instances did the variation amount to more than a remove of one place from that which contained the largest number of larvæ, and which therefore represented the normal result of the food-plant for each particular experiment. In such a calculation the differences between the larval colours are arranged in five classes, *i.e.*, white, whitish intermediate, intermediate, yellowish intermediate, and yellow. The difference between any two of these is very small, and hence it is seen how entirely insignificant was the amount of individual variation even in the few cases in which it occurred. In one instance only was there a variation on both sides of the normal result, *i.e.*, in Series III, Nos. 11, 12, 13, where seven larvæ fed upon *S. cinerea* became intermediate in one case, yellowish intermediate in five cases, and yellow in one case. Here there is a difference of two places between the extremes, but one larva only varied in each direction, while five remained normal. Thus, although this is by far the most striking instance of individual variation met with in about a hundred bred larvæ in 1884—1885, it is by no means extreme, and cannot alone explain such excessive variations as have been met with in the field out of about an equal number of instances. I refer especially to the instance recorded in my last paper (p. 302), in which a bright yellowish variety was found upon apple, the divergence from the normal result being as wide as possible (five places). Another almost equally striking instance was met with this year (as will be recorded) upon *S. cinerea* in the field, one larva being whitish intermediate and four others yellowish. Here the divergence amounts to four places, and compares in an interesting way with the lesser divergence in the larger number of larvæ bred upon the same plant. A divergence equal to that upon *S. cinerea* was recorded in my last paper (p. 301) upon *S. ferruginea*, one larva being yellowish and three whitish intermediate. It is possible or even likely that considerable divergence is occasionally caused by individual variation, but that this is not the only or indeed the chief explanation of the few instances of extreme divergence recorded, is proved by the fact that such variation only occurs when the probabilities are greatly in favour of correspondingly different hereditary tendencies, and that

a much greater uniformity prevails when the larvæ are bred from the same batch of eggs. The former argument is enforced by the fact that the captured divergent larvæ are sometimes of different age (and therefore probably of different parentage) from the normal larvæ upon the same tree. It must be clearly understood that in speaking of these extreme divergences in the field, I am not alluding to such instances as Mr. Boscher's eighteen yellow larvæ upon *S. viminalis*, or my own instances of yellow larvæ upon crab. I believe that these are to be interpreted in another way which will be explained later. There are altogether three factors which determine by their relative predominance the colour of these larvæ: (1) the tendency produced by the food-plant; (2) the hereditary larval tendency; (3) individual variation. (It does not signify for the present purpose whether the third factor is a definite and independent tendency, or merely a variable disturbance of a normal equilibrium between the first and second factors, or an irregular recurrence to the influences of earlier generations.) Of these three factors the third has been shown to be comparatively unimportant, while many extreme exceptions are explicable by the second. But I shall show later that the first factor may also produce variable results in the case of the same food-plant, and it is to such a cause that we must refer the interpretation of the conflicting testimony concerning the effects of *S. viminalis*, &c. At the outset it would be unlikely that the other two factors could have produced the exceptions (upon *S. viminalis*, &c.), because of their number and uniformity upon certain varieties of the food-plant. (See Mr. Meldola's account of Mr. Boscher's captures, pages 241 and 306 of the English translation of Weismann's "Studies in the Theory of Descent," Part II.) I was very interested to find that two of the bred larvæ possessed the red spots. In my last paper I pointed out (p. 309) that the occurrence of the spots upon the yellowish variety only was an "argument against the conclusion that these effects are in any way due to the food-plants." It was, therefore, very satisfactory to find a spotted larva which did not advance beyond the intermediate variety, and which at an earlier stage was even whiter. (Series III, No. 17.) The other instance was in accordance with the observation (which was universal until the above recorded instance appeared) that the spots are always found upon yellow varieties, for out of about a hundred bred larvæ in 1884 and 1885, there was only one yellow variety, and this, with one exception, was the only red spotted larva. But if the spots were always necessarily connected with one variety, this would not prove that there could be no larval colour modifications, depending on the colour of the food-plant (in fact nothing can do away with this conclusion now that it has so firm a basis of experimental proof). There are many reasons for thinking that the ancestral form of the larva was yellow, brightly spotted, and ornamented

in other ways which are suggested in the larval ontogeny. (See "Proc. Ent. Soc. London," 1885, Part II, August, pp. 290—296.) The newly hatched larvæ are always brightly yellowish even when fed upon apple. The particular form of protection now gained by the larva, by a resemblance to the foliage of its food-plant, has involved the laying aside of this ornamentation, but some of its features occasionally appear (by reversion), and when this is the case they are associated in nearly all cases with the ancestral ground-colour. It is possible that the differences of ground-colour which are now dependent on the food-plant arose independently, and persisted for a long time as ordinary cases of dimorphism or polymorphism, and that their relation to the colour of the food-plant was determined by natural selection at a much later date. But although the differences may have commenced in this way, they did not probably reach anything like their present condition until they came to depend on the food-plant, for without such a relation the colours would often render the larva conspicuous instead of protecting it.

4. *Observations in the Field upon Larvæ of* S. ocellatus *during* 1885.

The larvæ were very abundant last year and the results were more uniform than in 1884. An account of all the captured larvæ is given below.

August 2nd.—Upon *Salix rubra* in some fields by the River Cherwell, near Oxford, seven nearly full-grown larvæ and one small in the fourth stage, which was a bright yellowish variety. Of the former number four were bright yellowish varieties, and three were well on the yellow side of intermediate, almost good yellow varieties. Also upon *S. cinerea* in the same locality, one nearly adult larva which was a good yellow variety. Also upon a small tree of *S. babylonica* in a garden at Oxford (the same tree upon which seven larvæ were found in 1884; see "Proc. Roy. Soc.," No. 237, 1885, pp. 301 and 302), one nearly full-grown larva decidedly on the yellow side of an intermediate variety but not strongly yellowish.

August 3rd.—Upon *S. viminalis* on the River Cherwell, near Oxford, three larvæ in the last stage (upon the same tree) of which one was nearly adult and rather yellowish, but not more than an intermediate variety; while the other two were much less advanced in the last stage, and were whitish varieties.

August 4th.—Upon *S. rubra* by the Cherwell (as above, August 2), two nearly adult bright yellowish larvæ.

August 9th.—Upon *S. rubra* by the Cherwell (as above), one nearly adult bright yellowish larva. Also upon *S. cinerea* in the same locality, two almost full-fed larvæ which were good yellow varieties. Also upon *S. linearis* in the University Parks, one larva which was perhaps slightly on the yellow side of an intermediate variety.

August 16th.—Upon *S. rubra* by the Cherwell (as above), one nearly adult bright yellowish larva. Also upon *S. cinerea* in the same locality two nearly adult larvæ (on the same bush), of which one was slightly on the whitish side of an intermediate variety, while the other was a rather bright yellowish variety. Also upon *S. triandra* in the same locality one almost full-fed bright yellowish larva.

August 23rd.—Upon *S. Smithiana* at Binsey upon the Isis, near Oxford, one nearly adult larva on the whitish side of an intermediate variety. Also upon *S. triandra* in the same locality, one nearly adult bright yellowish variety. Also upon *S. triandra* upon the Isis at Medley Weir near Oxford, one bright yellowish larva which had just entered the last stage.

August 25th.—Upon *S. rubra* (Cherwell) three small larvæ towards the end of the third stage, all strongly yellowish varieties, but differing somewhat in intensity.

August 30th.—Upon *S. triandra* close to the bridge at Ferry Hincksey, near Oxford, one nearly adult larva which was a good yellowish variety, but rather whitish on the back. Also upon ordinary apple in a garden at Oxford one very white variety at the end of the fourth stage (changing its skin).

September 11th and 12th.—Upon a variety of *S. alba* with small narrow leaves, having smooth greenish under sides; in a dry part of the bed of the river at Visp, Switzerland, two full-fed strong yellow varieties (although not the strongest because of the want of a distinct yellow tinge to the under surface). Both had the very sharply marked and distinct white stripes which are often found on larvæ with this tint of ground-colour. Also September 12th, near the stream which flows through Brigue, Switzerland, three larvæ upon different species of sallow. Upon a variety of *S. alba* very similar to the above (? *S. vitellina*), an adult intermediate variety rather strongly tending towards the yellowish form upon its dorsal surface, and having very distinct white stripes, such as were possessed by the larvæ from Visp. Upon *S. incana*, a yellow variety of the larva, looking as though it would have been very yellow if it had been in a healthy condition. But the larva, which was well in the last stage, was much stunted and in very bad health, having been attacked probably by some parasite, and pierced in twenty-eight places. Also upon *S. alba* (the leaves much like the common English form), a larva which was advanced in the last stage, and an exceedingly white variety—the palest I have ever seen. There was a little yellow on the under side, but it was not at all the tint of the yellowish varieties, and indicated no transition in that direction. The larva did not seem to be very healthy. It possessed in common with all very strong white varieties a distinct trace of the subdorsal line for its whole length, and there was a trace of the darkening for a border to a "ninth stripe" upon the third

thoracic segment in front of and parallel with the more distinct and larger "eighth stripe" upon the first abdominal segment.

5. *Experiments upon captured Larvæ.*

Being engaged in the extensive breeding experiments already described, I did not attempt much with the captured larvæ, especially as nearly all of the latter were full-grown when found. The strongly yellowish larva in the fourth stage, found August 2nd on *Salix rubra*, was put upon apple on August 3rd, when it was 24 mm. long. On August 27th it was 51 mm. long, and was much affected by the change of food, being an intermediate variety, or perhaps slightly on the yellowish side of intermediate. It was interesting to note that the change of colour affected the shagreen dots, which became white, having been formerly yellow as in all strongly yellowish varieties.

6. *Conclusions arrived at by the Consideration of the captured Larvæ: The Reconciliation of conflicting Evidence.*

The colours of the captured larvæ were wonderfully uniform for their respective food-plants. *Salix rubra* produced a large number of yellow larvæ, and others which were but little removed from yellow. The larva upon *S. babylonica* resembled these latter. *S. triandra* also produced yellow larvæ, and so with *S. cinerea* (with one exception). There was but little confliction in the results of *S. viminalis*, and *S. Smithiana* produced a normal larva, and the colours of the Swiss larvæ (with the exception of that upon *S. incana*) might have been almost exactly anticipated by investigating the colour of the under sides of the leaves. Thus there are fewer exceptions than in the larvæ captured in 1884, and yet among them was one instance which suggested to me the explanation of those conflicting results which have been the chief obstacle to the complete acceptance of my theory of the colour-relation between food-plant and larva; I mean especially the immense difference between Mr. Boscher's experience (quoted by Mr. Meldola as above referred to) and my own with regard to *S. viminalis*. The larva which suggested the interpretation was the yellowish intermediate variety found August 9th upon *Salix linearis*. I had much wished to find a larva upon this foreign species of Salix, of which there are many fine specimens in the Oxford University Parks; for I had noticed for over a year that the under sides of the leaves were more densely covered with down and whiter than any species of Salix I had ever seen, and even more so than apple. The upper sides of the leaves were dark-green and glossy, and the leaves were narrow, pointed, and very small, and extended at right angles to the twigs. The leaves resembled those of *S. viminalis*, only they were much smaller and whiter underneath. I thought that such a tree must produce the most extreme white varieties, and I was

greatly astonished at the colour of the single larva found upon it. Thinking over such a result, I remembered that the one bright yellow variety which I had found upon *S. viminalis* (on August 11, 1884; see p. 301 of the above-mentioned paper) was upon a variety of the latter plant with very small leaves, while the white larvæ were found upon the large-leaved variety which is the common one at Oxford. Shortly afterwards, through the kindness of Mr. Boscher and Mr. William White, I had the opportunity of looking at some twigs of the trees upon which the eighteen spotted yellow larvæ were found (see p. 304 of the former paper, &c.). *The trees were the small-leaved variety*, and Mr. Boscher states that all the yellow larvæ were found upon such food-plants. Then again I remembered that in the case of the very bright yellow variety found upon crab (*var. acerba*) on August 14th, 1884 (see former paper p. 301), the latter tree had very small leaves. Finally, *Salix incana* at Brigue possessed leaves which were very white and downy underneath, but they were very small, and the larva found upon the tree was yellow.

All this convergent evidence suggested the following explanation. The larvæ are only affected by that part of the environment which is so close to them as to be almost or quite in contact; the tint of mature life is (as far as it is caused by the colour of the food-plant) a resultant of the conflicting tints which have formed part of the immediate environment of the larva throughout its life, and the ultimate predominance of one larval tint is due to the relative proportion of the whole larval life during which that tint predominated in the environment. This conclusion is also supported by the breeding experiments and the experiments upon captured larvæ. Such being the case, the ultimate whiteness of a mature larva is largely due to the considerable proportion of its earlier life which is spent upon the white under sides of the leaves. (The young larvæ invariably take up this position.) During this period white is the only colour in its immediate environment, except when it is actually engaged in eating, and so may perhaps be affected to some extent by the colour of the upper sides. But when the larva reaches a certain size and weight, it must in nearly all cases quit this position and retire to the stem, because the leaf is not strong enough to bear it without being dragged into an unnatural position, or because it is too small to form a background for the larval body. Therefore the time at which it retires must chiefly depend upon the size and strength of the leaves. Having once quitted the small leaves the larva does not again rest upon them, because they can be entirely eaten from the stem, whereas the large leaves cannot be reached without venturing upon them, and therefore in the latter case, the chances are in favour of the larva being left upon a partially eaten large leaf during many of the periods of rest, even at an

advanced stage. When the larva is smaller and eats much less it remains on the same leaf for many days. But directly the larva rests on the stem the tints of its immediate environment alter, for they are then due to the colours of both sides of the leaves and of the stem itself. The relative predominance of the colours of the two sides of the leaves depends upon the position of the larva and the arrangement of the leaves. But the position of the larva is uniform (except when it is wandering to a fresh twig), the head being always directed towards the apex of the stem. Hence in the case of food-plants whose large leaves regularly droop over from the vertical twigs, or are curved in the usual way with the concavity downwards, the tints of the under side still predominate after the larva has retired to the stem, and they will still form almost the only effective colour as was the case in earlier periods. When, however, the leaves hang irregularly or spread out horizontally from horizontal twigs, the colours of the two sides may be equally important, or may depend (in the latter case) upon the side of twig on which the larva rests.

This explanation of course will apply but little to leaves of which the upper and under surfaces are approximately similar in colour, and accordingly there is very little conflicting testimony from such food-plants (*Salix rubra*, *S. babylonica*, *S. triandra*), and such as there is, is mainly explicable by variations in the other two factors which go to influence larval colour. But even in these plants there is some difference between the colours of the two sides which would have an effect upon the larvæ, as was proved by the experiment in which the bloom was rubbed off in the case of *S. triandra.* But in the case of leaves with strongly white under sides such an explanation accounts for all the conflicting evidence met with in the field (due to this factor and recognised by the uniformity cf results from trees with leaves of a particular size and arrangement). Thus when I expressed the opinion that *Salix viminalis* produces white larvæ I was thinking of our common long-leaved variety. The leaves of this variety often grow 6 inches long near Oxford, and quite three-quarters of an inch wide. Such leaves would retain a larva until the end of the fourth stage, and often far into the last stage. Furthermore the long leaves droop over very regularly from the higher vertical twigs upon which the larvæ are generally found, and so present their under sides to the stem and to a larva resting upon it. On the other hand, the leaves of the other variety are much smaller (from memory I should say that they are often about an inch and a-half long and three-eighths of an inch wide), and often hang in irregular wisps from the more vertical twigs, or droop vertically from the more horizontal branches. Thus such a variety of leaf would retain the larva for a comparatively short time, and after its retirement to the stem the colour of the immediate environment would be as largely due to the

upper as the under side. Hence the effect of the narrow and small-leaved *S. viminalis* in producing yellow larvæ, and the exceedingly white-leaved (under sides) *Salix linearis* in producing a yellowish intermediate larva. The influence of *S. cinerea* (in the direction of yellow) is probably in a great measure due to the same facts, for its small leaves are often downy underneath, and are always much whiter than those of *S. rubra*, &c. The much stronger influence of *S. Smithiana* towards white is probably due to its much larger but very similar leaves. It is likely that some of the irregular results referred to other factors may be explained in this way. Thus it was very obvious that the leaves of *S. ferruginea* (?), upon which very differently coloured larvæ were found (p. 301 of the former paper), varied very much in size, those on the lower branches looking like rather narrow leaves of *S. cinerea*, the upper ones being exactly like those of *S. Smithiana;* but in such an isolated case it is not possible to determine certainly which of the factors caused the exception, or whether it was due to a combination of causes. I think it is unlikely that any great difference could be caused by a slight variation of habit in larvæ, *i.e.*, in the period at which different individuals would retire to the stem from leaves of the same size. It is probable that the habit is very uniform, and always leads the larvæ to remain on the leaves as long as the size and strength of the latter will permit them to do so. In *Salix alba* the question is complicated by the fact that after the larva retires (early in this case) to the stem, the whiteness of the environment will partially depend upon nearness to the apices of the twigs, for the upper sides of the young leaves are white as well as the under sides. The exceedingly strong influence of apple is readily explicable by the considerations advanced above; for the leaves are large, broad, and strong, and will take the weight of a larva advanced in the last stage without bending. The single larva found upon apple in 1885 (August 30th) was resting before changing its skin for the last time on the under side of the leaf, and I have often before found the large larvæ in the same position. After the larva retires to the stem the apple leaves form broad curved white surfaces, which everywhere environ the (presumably) sentient part of its body, which is always directed during rest towards the apex of the twig. Upon all the varieties of food-plant, and especially upon apple, the larva tends to rests upon the young and vigorous twigs which stand out from the trees and bear fewer larger leaves at wider intervals, and with more regular arrangement than those upon the older wood below. Thus the larva gets the maximum effect from the under sides of the leaves after it has retired to the stem. This explanation also helps towards clearing up the difficulty about the irregular effect of crab. Although the under sides of the leaves are smooth and green, they are generally of a

whitish-green, and I think that a white larva is better protected when resting on the under side of the leaf than a yellow larva would be, although this is often true in the case of trees which are known to produce yellow larvæ. Again the leaves are large as a rule, and so the larvæ are advanced when they rest on the stem, and even then the arrangement of the leaves and the position of the larva cause the under side to contribute most colour to the immediate environment. I have already mentioned that the bright yellow, red-spotted larva captured in 1884 upon crab, *var. acerba*, was upon a tree with exceedingly small leaves. Furthermore, in this variety the leaves are extremely variable in size upon different parts of the tree. But although the conditions mentioned above may have conduced towards the fact that my bred larvæ fed upon this plant became so white, I cannot but think that such a result was largely due to their strong hereditary tendency towards this colour, for the crab cannot compare with ordinary apple in the whiteness of the under sides of the leaves, nor is it in this respect equal to *Salix viminalis*, *Smithiana*, or even *cinerea*. I think that this food-plant more than any other requires further experimental work with larvæ of all varieties of hereditary tendency, but it is very unfortunate that the larvæ do not seem to thrive upon the plant, at any rate in confinement.

Another great difficulty is, I think, completely explained by the above-mentioned consideration. I mean the fact that bred larvæ tending strongly towards white, became intermediate in 1884 and in many cases in 1885 when fed upon the large-leaved variety of *Salix viminalis* (for I have always fed my larvæ upon this variety). In order to obtain the best leaves I have to walk to the Cherwell and take a boat; and as this is not always convenient, I bring home and give to the larvæ a great quantity. The leaves being very long and crowded in the glass cylinders in which the larvæ are kept, their natural arrangement is entirely altered, so that the upper sides are presented to the larvæ to a much greater extent than happens on the tree. The result is to affect the environment of the larvæ upon the leaves as well as those upon the stem, for in the former case the upper sides of other leaves must be often crowded close up to the under side of the one upon which a larva is resting. Furthermore, the leaves do not last so long without withering as upon the trees in the open air, and therefore the larvæ are frequently compelled to wander on to fresh leaves, and in so doing they must be affected by the colour of the upper as well as the under sides. In the future it would be well to breed some larvæ in large cases which would hold the twigs without overcrowding, and would permit the leaves to fall naturally. In the case of apple the arrangement of the leaves has not been disturbed in the cylinders, because I can get the twigs in my garden, and because the leaves are of a more manageable shape.

It is possible that the same causes have helped to produce yellower results than are normal in the breeding experiments with *Salix alba* and *S. Smithiana*, for these leaves have been somewhat disturbed, although not nearly so much as in the case of *S. viminalis.* I do not doubt the validity of this explanation for the latter plant, and the results of experiments are thus satisfactorily interpreted which have been sources of difficulty and uncertainty since the summer of 1884. This explanation also clears up what I felt to be a great difficulty in my former paper when I wrote the words (page 314) "it is only the part of the environment imitated which produces any effect, *e.g.*, the under sides of the leaves in the case of *S. ocellatus*, and yet the environment, of course, includes both surfaces." I have shown above that the effective part of the environment—the immediate environment—does *not* in many cases include both surfaces, but either entirely or chiefly the under surface, *i.e.*, that which is *ipso facto* imitated, and when it does include the other surface for a sufficiently long period, a different effect is produced (in the case of leaves with differently coloured sides). It is therefore obvious that when we speak of the tendency of a plant to produce a certain colour, we mean a tendency from the size and arrangement of the leaves to encourage a larval position in which the effective colour of the environment is only contributed by one leaf surface, or, on the other hand, a tendency to change the larval position into one in which both surfaces may become equally effective, or, again, into one in which either of them may predominate. In this explanation of what is meant by the tendency of a plant, I am, of course, especially referring to those with leaves having white under sides; but it will probably apply to some extent in nearly all cases, for there is always some difference between the two sides of the leaves.

There is one other comparison between the captured and bred larvæ which is a source of difficulty. The exceedingly uniform results upon *Salix rubra* in the field (I have found altogether twenty-two larvæ, of which eighteen were yellow, three yellowish intermediate, and one intermediate) render it more than probable that the plant has possessed an influence sufficiently powerful to reverse a larval tendency in the direction of white (for it is very unlikely that in all the eighteen instances of a maximum result the larva happened to tend in the same direction as the food-plant); and yet in the breeding experiments, out of nine larvæ eight were yellowish intermediate and one intermediate; and thus in no case has the food-plant completely overcome a strong tendency (1884) or a somewhat modified tendency (1885) towards white.

I have thought that part of this difference (also observable in the cases of *S. babylonica* and *S. triandra*) may be due to the fact that the tops of the glass cylinders in which the larvæ are bred, are covered

with white muslin, which probably, therefore, produces some slight effect on the larvæ. Again the larvæ in the field are probably affected by the amount of light, and especially direct sunlight, which must brighten the colours of their environment. I have commonly found them on *S. rubra* (as in the other trees) upon the higher younger branches standing out from the trees, and especially during the past summer upon twigs that have been allowed to grow out from the tops of hedgerow sallows; and I have also noticed that they are better protected in these strong lights because of the brightness of their own colour than in the shadows of the lower and more crowded leaves. The bred larvæ have never been so freely exposed to light, and although the small leaves of the food-plant do not become much disarranged (probably hardly any effect would be produced if they were), yet the crowding certainly helps to shade the leaves and to diminish the brightness of their colours. (During the past summer I have kept the larvæ under a north window to protect them as far as possible from the excessive heat.) It is very probable that some of the difference is to be explained in this way, but most of it is no doubt due to the hereditary tendencies of my bred larvæ, which were always towards white, while this tendency is probably less common than the other by the banks of streams (see former paper, p. 310). It will be very interesting in future experiments to breed the larvæ under yellow and under white glass. Next year I hope to be able to make such experiments.

7. *The Whole of the Evidence Summarised.*

I have arranged all the results hitherto obtained in a table which is printed below. The only important omission is the hereditary tendency of the bred larvæ, and this would have rendered the table too complicated, for there were four different series in 1885. It will, however, be remembered that all the larvæ bred in 1884 tended strongly towards white, while nearly all of them in 1885 possessed the same tendency in a slightly modified form. All the numbers without reference marks refer to my own observations or experiments conducted at Oxford; while special marks call attention to the work of other observers, or to my own work in other localities. The 204 instances given below comprise all the cases in which the colour of the larva and the name of the food-plant have been noted, either in breeding or in field observations.

Only in the case of the white varieties captured upon ordinary apple have I ventured to allude to the larvæ under the vague term "very common," because such has been my experience and that of other observers, although no list of instances has been kept, and therefore no number can be quoted. Had I left the space blank it would have conveyed an entirely wrong impression of a very general experience. It must be understood that in the following descriptions

Food-plant.	Description of under sides of leaves.	Size of leaves.	Nature of evidence.	Dates.	Colour of larvæ. White.	Whitish intermediate.	Intermediate.	Yellowish intermediate.	Yellow.	Totals.	Additional notes and general conclusions.
Apple	White pubescent	Large and broad	Breeding experiments	1884	5	..	..	..	..	5	Tends very strongly towards the most typical variety. Only one exception yet known, although this was upon a tree which was in every way normal.
				1885	6	..	..	..	..	6	
				Other dates	3*	..	..	..	..	3	
			Observations in the field	1884	1†	..	..	..	1†	2	
				1885	1	..	..	..	..	1	
				Other dates	Very common						
				Totals	16	..	..	..	1	17	
Apple .... (under sides)	Ditto	Ditto	Breeding experiments	1885	1	..	..	..	..	1	The same effects as the normal leaves.
Apple .... (upper sides)	(Upper sides are dark green and glabrous)	Ditto	Breeding experiments	1885	3	..	..	..	..	3	I am not yet satisfied that the reverse effects may not be produced. The larvæ did not arrive at maturity.

* Mr. E. Boscher's observations and experiments at Twickenham.

† In a garden at Reading.

Crab ...... (cultivated)	Whitish-green and glabrous	Ditto	Breeding experiments	1884	5	..	..	..	..	5	Very contradictory results. The effect of this plant needs reinvestigation with larvæ inheriting all varieties of tendency. The bred larvæ evidently inherited strong tendencies towards the whitish variety.
			Observations in the field	Other dates	..	..	..	..	2†	2	
				Totals	5	..	..	..	2	7	
Crab (wild) var. *acerba*	Green and glabrous	Broad, very variable in size, but generally smaller than those described above	Breeding experiments	1885	9	..	..	..	..	9	Same conclusions as those given above. The bred larvæ were supplied with leaves of different sizes. The captured larva was upon a very small-leaved tree. The former larvæ inherited strong tendencies towards the whitish variety.
			Observations in the field	1884	..	..	..	..	1	1	
				Totals	9	..	..	..	1	10	
Salix viminalis	White, with dense satiny down	Long and narrow, extremely variable in size	Breeding experiments	1884	..	..	4	..	..	4	The large-leaved varieties tend towards white, the small-leaved forms towards yellow. The bred larvæ were fed upon large leaves, but their tendency was somewhat modified by the displacement from their natural position, which resulted from crushing them into the breeding cages. The nineteen captured yellow larvæ were upon the small-leaved variety: two of the white ones were upon the large-leaved form, and the other two, with the intermediate larva, upon a tree with leaves of an intermediate size.
				1885	4	5	..	..	..	9	
			Observations in the field	1884	1	..	..	..	1	2	
				1885	2	..	1	..	..	3	
				Other dates	1	..	..	..	18* (about)	19	
				Totals	8	5	5	..	19	37	

* Mr. E. Boscher's observations and experiments at Twickenham.

† In a garden at Reading.

Food-plant.	Description of under sides of leaves.	Size of leaves.	Nature of evidence.	Dates.	Colour of larvæ. White.	Whitish intermediate.	Intermediate.	Yellowish intermediate.	Yellow.	Totals.	Additional notes and general conclusions.
S. viminalis (under sides)	Ditto	Large-leaved varieties were used	Breeding experiments	1885	1	..	..	..	..	1	Probably always towards white.
S. viminalis (upper sides)	(Upper sides are generally dark green, and glabrous)	Ditto	Breeding experiments	1885	..	..	1	..	..	1	Probably always towards yellow.
Salix linearis (Forbes)	Whiter and with denser down than the last	Very small and narrow	Observations in the field	1885	..	..	.	1	..	1	Probably towards intermediate, or either side of it, according to the leaf-surface, which forms most of the immediate environment.
Salix incana	Like *S. viminalis*	Long, narrow, and small	Observations in the field	1885	..	..	..	..	1†	1	Probably towards yellow, like the small-leaved *S. viminalis*.
Salix alba	The young leaves with a glistening silky down, present but less obvious on the older leaves	Moderate size, like those of *S. triandra*, but smaller	Breeding experiments	1885	..	..	..	2	..	2	Evidently strongly towards white, as shown by the 20 instances in the field. The bred larvæ may have been affected by disarranged leaves, and they did not reach maturity.
			Observations in the field	1885	1†	..	..	..	..	1	
				Other dates	19*	..	..	..	..	19	
				Totals	20	..	..	2	..	22	

* Mr. E. Boscher's observations and experiments at Twickenham.

† In Switzerland.

Salix alba, ? var. *vitellina*	The whole effect green, with a bluish-white "bloom." Quite smooth and downless	Narrow and small	Observations in the field	1885	..	..	..	1†	..	1	Probably the tendency is generally towards yellow.
Salix alba var. ?	Ditto	Ditto	Observations in the field	1885	..	..	..	..	2†	2	Almost certainly a normal result.
Salix Smithiana	White, with dense satiny down	Large and rather narrow, but vary much in size on same tree	Breeding experiments	1885	..	4	..	1	..	5	Larvæ found on the large leaves. Probably the tendency is towards the white side of intermediate, the other varieties having become more affected by the colour of the upper sides. Leaves of the next tree were sometimes used in breeding these larvæ.
			Observations in the field	1884	..	1	..	1	..	2	
				1885	..	1	..	..	..	1	
				Totals	..	6	..	2	..	8	
Salix ferruginea, Anderson (probably)	Similar to *S. Smithiana*	Similar to *S. Smithiana*	Observations in the field	1884	..	3	..	..	1	4	Same results as with *S. Smithiana*. Mr. J. G. Baker, of Kew, thinks that the tree is *S. Smithiana*.
Salix cinerea	Reddish, glaucous, or ashy, downy sometimes, and the amount of down variable. A very variable species	Broad but small	Breeding experiments	1884	..	..	4	..	..	4	Probably generally towards yellow, but exceptions are to be expected, and are, I think, better protected on this tree because of the "dead" appearance of the generally light coloured under sides.
				1885	..	..	2	6	1	9	
			Observations in the field	1885	..	1	..	..	4	5	
				Other dates	..	..	..	..	3‡	3	
				Totals	..	1	6	6	8	21	

† In Switzerland.

‡ Two at Reading, one at Oxford.

Food-plant.	Description of under sides of leaves.	Size of leaves.	Nature of evidence.	Dates.	Colour of larvæ.					Totals.	Additional notes und general conclusions.
					White.	Whitish intermediate.	Intermediate.	Yellowish intermediate.	Yellow.		
Salix triandra	The whole effect is green, but a whitish "bloom" is present. Smooth and downless	Generally large, but varying, rather narrow	Breeding experiments	1885	..	..	6	2	..	8	Evidently in the direction of yellow.
			Observations in the field	1885	..	..	..	..	4	4	
				Totals	..	..	6	2	4	12	
S. triandra (without bloom)	Ditto, without the bloom	Ditto	Breeding experiments	1885	..	..	..	10	..	10	More strongly than the last in the direction of yellow.
Salix babylonica	Like *S. triandra*, only the "bloom" is bluish-white	Small and narrow	Breeding experiments	1885	..	..	1	4	..	5	Strongly in the direction of yellow.
			Observations in the field	1884	..	..	..	6	1	7	
				1885	..	..	..	1	..	1	
				Totals	..	..	1	11	1	13	

Salix rubra	Ditto	Small and rather narrow	Breeding experiments	1884	..	..	..	5	..	5	Ditto.
				1885	..	..	1	3	..	4	
			Observations in the field	1884	..	..	1	..	3	4	
				1885	..	..	..	3	12	15	
				Other dates	..	..	..	..	3	3	
				Totals	..	..	2	11	18	31	
Populus nigra	Light green and glabrous	Large and broad	Breeding experiments	1885	..	..	1	..	..	1	Insufficient evidence. I should expect tendency towards yellow.
									Complete total ..	204	

All are my own observations and experiments except the three numbers marked *. All the unmarked observations and experiments took place at Oxford.

of the under sides of the leaves and their size, I am alluding to the trees upon which the larvæ mentioned in the table were found or were bred. There may be varieties in many cases to which my descriptions would not apply.

8. *Conclusion.*

A glance at the table printed above will at once show the nature and amount of the evidence for the conclusion that the larva of *Smerinthus ocellatus* maintains a colour-relation with the food-plant upon which it was hatched, adjustable within the limits of a single life, and that the predominant colour of the food-plant itself is the stimulus which calls up a corresponding larval colour. This may seem to be a long paper to prove the existence of such a relation for a single species, but it must be remembered that in accepting the conclusion now arrived at, we are admitting the existence of an entirely new resource in the various schemes of larval protection by resemblance to the environment, and one which stands on a very different level from all the others; in these the gradual working of natural selection has finally produced a resemblance—either general or special—to something which is common to all the food-plants of the larva, or to some one or more of them, the larva being less protected upon the remainder; but in this case the same gradual process has finally given the larva a power which is (relatively) immediate in its action, a power which enables the organism itself to answer with corresponding colours the differences which obtain between its various food-plants. And the action differs no less from the superficially similar cases of much more rapid changes in the colour of other organisms (amphibia, fish, &c.) corresponding to the changing colours of their environment, for in such organisms the external colours act as a stimulus which, through a nervous circle, modifies the condition of existing pigments; while in the larva it is the amounts and kinds of vegetal pigments made use of and larval pigments deposited that are affected. The influence, in fact, makes itself felt by affecting the absorption and production of pigments rather than their modification when formed; and such a method of gaining protection is, as far as we yet know, unique in the animal kingdom. And such a power is not confined to the species in which its existence has been to some extent completely proved. There are already proofs that many others can maintain a similar colour-relation (see my former paper, and the references given by Mr. Meldola in his translation to Weismann's "Studies in the Theory of Descent," Part II), and I am sure that careful observation will reveal many slight and protective differences among larvæ of the same species when found upon differently-coloured food-plants, and will prove that this power is not at all uncommon among the great

body of lepidopterous larvæ which adopt the methods of protective resemblance. Furthermore, it is very probable, as suggested by Professor Meldola, that the colour of the environment will prove to act as one of the determining causes of the larval colours ultimately assumed by the individuals of dimorphic species (which are generally green and brown in lepidopterous larvæ). To show in what a light this colour-relation appears to Dr. August Weismann (whose essay upon "The Markings of Caterpillars" first induced me to work at these organisms), I quote the following sentences from a letter I received from him after sending him my paper in the "Entomological Society's Transactions," Part I, April, 1884, in which this subject is alluded to :—

"Dagegen verstehe ich nicht ganz, wie sie sich den 'phytophagic character of the ground-colour' entstanden denken. Ich habe augenblicklich mein Buch nicht zur Hand u. kann deshalb die Note von Meldola nicht nachsehen, erinnere mich auch derselben nicht. Sie scheinen zu glauben, dass die *Nahrung* der Raupe bis zu einem gewissen Grad ihre Farbe *direkt* hervorrufe. Ich wäre sehr begierig, einen Beweis dafür kennen zu lernen. Ich kann mir nicht denken, wie dies möglich sein, solle jedoch weiche ich den *Thatsachen!* Ich bin begierig, zu erfahren, ob Sie solche inzwischen gefunden haben."

I venture to hope that the facts spoken of by Professor Weismann are now satisfactorily demonstrated, not as proving the former theory to which he alludes, that the food itself causes the change of colour after it has been eaten by the larva, but as proving the existence of the more subtle form of influence described in the present and in my last paper. At the same time I must express my sense of the great extent to which I am indebted to Professor Meldola, to whom we owe the former theory, for without the most suggestive editorial notes to his translation of Weismann's work, and the experiments undertaken by Mr. Boscher at his request, it is most improbable that the present investigation would ever have been begun.

III. "On the Polarisation of Light by Reflection from the Surface of a Crystal of Iceland Spar." By Sir JOHN CONROY, Bart., M.A., of Keble College, Oxford. Communicated by Professor G. G. STOKES, P.R.S. Received January 27, 1886.

(PLATE 2.)

In the year 1819 Sir David Brewster communicated to the Royal Society ("Phil. Trans.," 1819, p. 145) an account of some experiments he had made on the polarisation of light by reflection from the surface